Development of a Venting/Termination System for Altitude Flight Control and Stability of High Altitude Balloons on Near-Space Missions

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Background

Hypersonic flight dynamics are complex and certain important issues, such as what can trigger laminar hypersonic flows to become turbulent, are not well understood; thus new advances in science need to be made before aircraft can be designed that can safely and routinely fly at many times the speed of sound [1]. A team of undergraduate and graduate student researchers in the Aerospace Engineering and Mechanics (AEM) Department, working on an AFOSR-funded MURI grant [2], are using optical particle detectors flown on weather balloon missions to characterize the particulate content of the stratosphere. Data collected will be used in computer simulations that study the onset of turbulence in hypersonic flows.

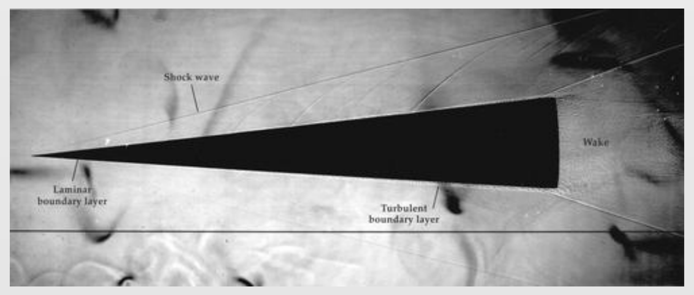


Figure 1: A shock wave emanating from the nose of a cone travelling at Mach 4 in a ballistic range [from Ref. 1].

Introduction

The purpose of this project was to build a low-cost venting system for the University of Minnesota's MURI Project which could be used to conduct "slow descent" stratospheric balloon flights from 120,000 feet to 80,000 feet altitude while also successfully terminating the flights, as commanded, at the end of those slow descents. "Slow descent" flights are desirable since they'll provide optimal conditions in which the MURI project can make stratospheric particulate measurements.

The project was inspired by an existing design by the University of Colorado at Boulder's MURI Project [6]. This project, however, investigated the venting capabilities of 1600 gram Hwoyee balloons, as opposed to Boulder, who use 3000 gram Kaymont weather balloons, which are five times more expensive.

Methods

We adopted many aspects of CU-Boulder's design, and then improved upon it, allowing us to interface with our 1600g Hwoyee balloons (which have much larger diameter necks) and also recover our vents (through the use of a termination/release mechanism) since it is our goal to recover all local MURI payloads. Our MURI collaborators in Florida and Colorado do not recover any of their vents or payloads.

The design of the venting system was very robust, but it was also made to be very quick and simple to build at the same time. Examples of some of the build techniques are shown in figures 2-6 below:

Figures 2-6: Soldering the custom PCB (fig. 2), method for cutting the helium port (fig. 3), result (fig. 4), push-rod method (fig. 5), result (fig. 6)

Several venting system prototypes were built (and flown) before an optimal design (both in terms of functionality and ease of build) was determined. Those prototypes, called "Vents 1-3," are shown below:

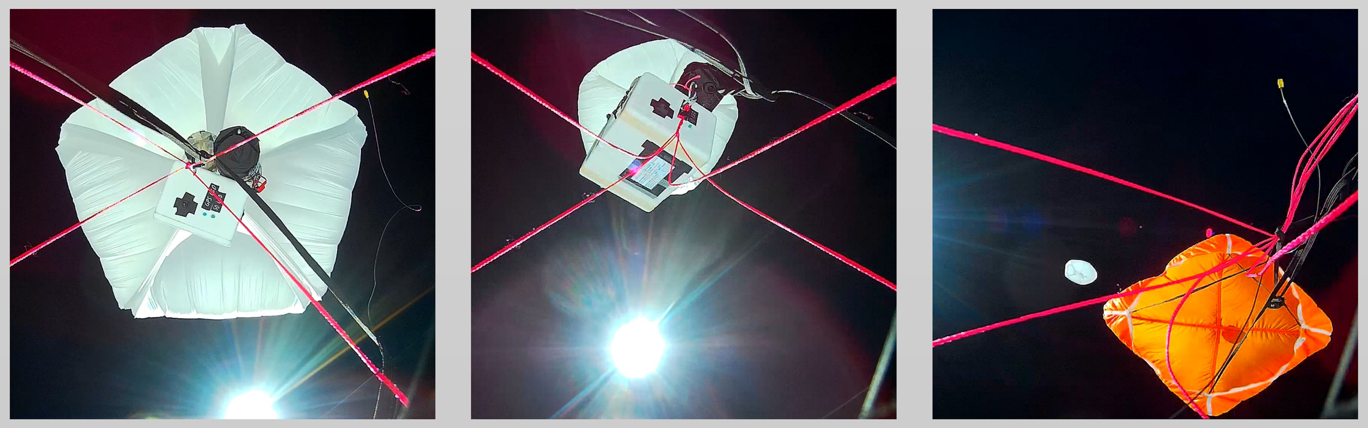
Figures 7-9: The three venting system prototypes, Vents "1-3," respectively.

As can be seen, many improvements were made between each iteration. The final iteration, "Vent 4," is shown in more detail below:

Figures 10-11: The ultimate design of our venting system ("Vent 4")

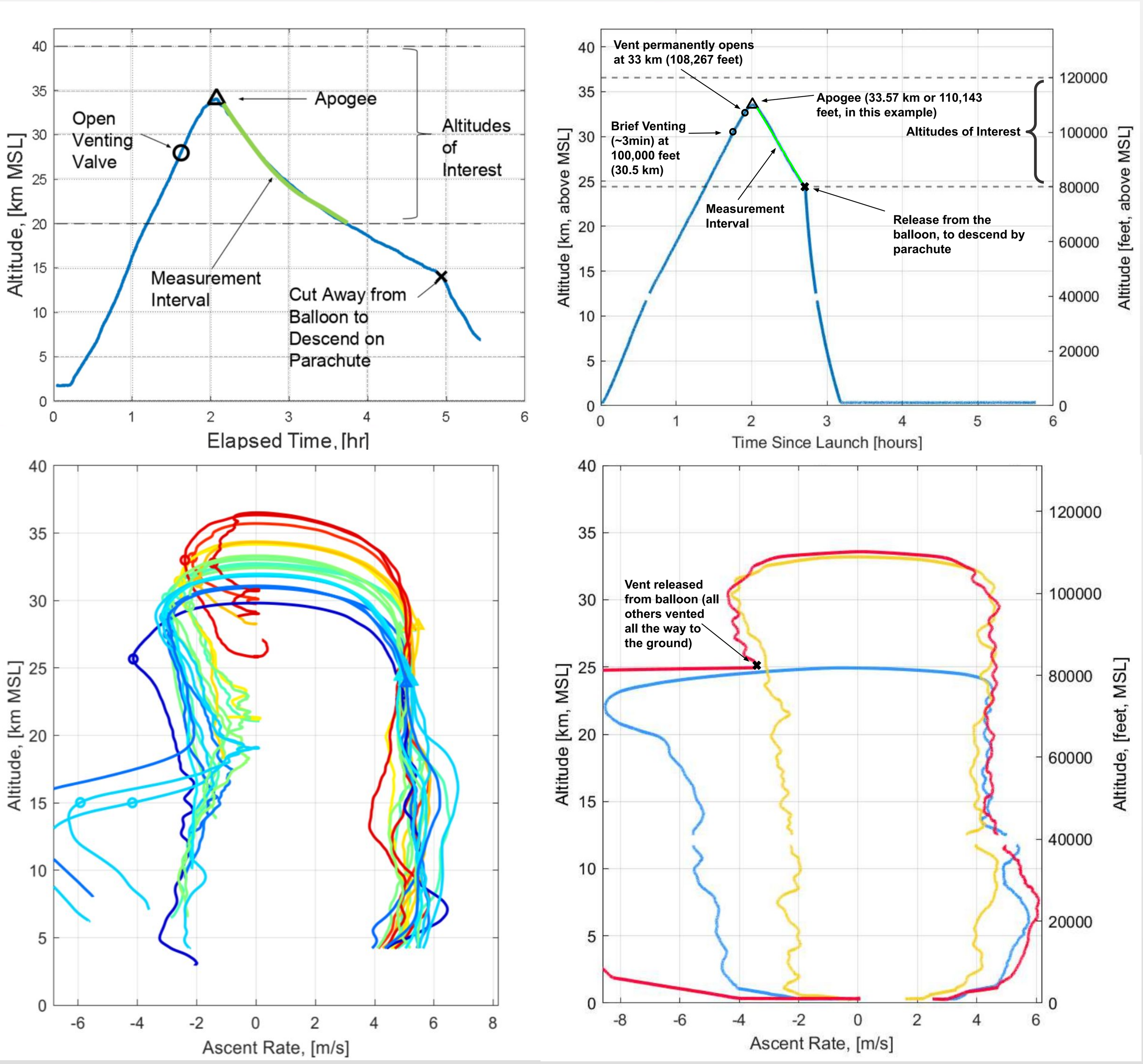
When venting, the servo, connected to the "flapper" (the bottom opener of the main tube) via the push-rod, rotates to its "open" position in order to simply open the vent. When closed, small magnets are used to passively keep the flapper well sealed throughout the flight.

While many different termination mechanisms were tried, by far the most successful method was the use of braided fishing line to hold the balloon neck to the vent (balloon neck restrained by string (white) in contact with two cut resistors (black) appears in the upper left on figure 10), then severing the fishing line using H-drivers to heat the resistors when release is desired.



Figures 12-14 (from left to right): Immediately before the "clean" release of the vent from a partially-deflated balloon, immediately after release/termination, and well after release/termination (balloon seen by itself, without the vent or any payloads, off in the distance)

Results



Figures 15-18: The top two plots (figs 15, 16) show the best performing vented flights to date for CU Boulder's vents and our vents, respectively, and the second set of plots (figs 17, 18) show the vented performance of twenty of CU Boulder's vented flights (left), and all three of our vented flights so far (right), respectively.

Future Work

Now that the testing and development phase of our venting and termination system is complete, our venting system will begin to be used for "slow descent" style MURI-Project flights beginning this summer. These "slow descent" style flights, which allow us to make our stratospheric dust particle measurements in slow, undisturbed air (not in the wake of a balloon, as is the case when ascending), will be critical in our efforts to accurately characterize the particulate content of the upper atmosphere. There will be great cost-savings with Hwoyee 1600g balloons (as opposed to CU's 3000g Kaymont balloons), local vented flights will now be recoverable, and vented performance may even be improved. The venting/termination system may also have a variety of other, non MURI-related, high-altitude ballooning applications going into the future, including in the upcoming U.S. eclipses in 2023 and 2024.

Acknowledgements

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